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CONTENTS

	PAGE
A Russian View of Humus	17
'D.D.T.': A New Insecticide	19
Shifting Cultivation	20
Suggestions for the Use of Growth Substances in the Vegetative Propagation of Tropical Plants	21
Native Foodstuffs in Tanganyika	32
Rusty Water and Malaria	39
Bush Encroachment	39
Chemical Notes	40

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A RUSSIAN VIEW OF HUMUS *

In recent years F. Yu. Gel'tser has published several papers and a book on the subject of humus formation. The thesis which she has developed is in some ways revolutionary; it represents the first serious attempt to break with the chemical concepts of humus inherited from the nineteenth century, and to substitute for them a biological concept. Most soil scientists would agree that the great mass of chemical work carried out in the past on humus has been almost fruitless of results.

Gel'tser defines humus not by any physical criterion such as colour ("all black substances are not humus, and all humus substances are not black") nor by the chemical properties of organic compounds extracted by strong reagents, but by the function of the material in the soil. Humus is that fraction of the organic soil colloids which possesses the capacity of combining with the mineral part of the soil to form organo mineral aggregates. In other words, humus is the stuff which creates a soil structure, and any organic material that does not take part in structure formation is excluded from the definition of humus.

The most significant part of this definition is the phrase "capable of combining with the mineral part of the soil." Other definitions of humus do not mention this property which distinguishes Gel'tser's humus from all other known organic substances. In order to appreciate Gel'tser's conception of humus it is necessary to rid the mind of traditional notions of humus that lay stress on its colour, its solubility in alkali, etc. According to Gel'tser humus may possess these properties—quite possibly it does, but there is nothing about them in the definition. Decomposed plant residues are not humus. Naturally they comprise a considerable part of the organic matter of many soils, but they do not possess the property of forming stable compounds with clay minerals. So far as is known, humus has no chemical affinity to any plant constituent. It is a product of bacterial synthesis. More specifically, it is the product of the autolysis of the bodies of bacteria which have developed on the hyphae of the fungi which carry out the initial processes of the decomposition of plant residues. Gel'tser has prepared such substances *in vitro*, and has shown that they possess a remarkable capacity of cementing clay particles into aggregates, and that they are very resistant to further microbial attack.

* Reproduced from *Soils and Fertilizers*, VII, No. 3, 1944.

That the first processes of decay are fungal is widely recognized by microbiologists. Gel'tser maintains that the ferments formed by dead vegetation produce at least locally the acid reaction necessary to give fungi predominance over bacteria. The dark-coloured, colloidal products of fungal decomposition are not, however, humus in the sense used by Gel'tser, for they are incapable of forming stable organo-mineral compounds with soil, for whatever length of time the fungal stage of decomposition proceeds. The black colloidal products obtained by autolysis of *Aspergillus niger* have the required property of humus of causing the aggregation of mineral soil particles and are regarded by Gel'tser as similar to, if not identical with, "active" humus, but she observed that they were obtained only after the fungal mycelia had become overgrown with rodshaped bacteria. Thus both fungal and bacterial processes play a part in humus formation.

Prolonged fungal decomposition takes place only in pronouncedly acid media. The richer the decomposing plant residues and the soil with which they are incorporated are in bases the more quickly is the initial fungus flora replaced by a predominantly bacterial flora, the products of the biological activity and autolysis of which form humus.

Gel'tser affirms that the rôle of lime in the formation of soil structure is not—or only to a minor extent—physico-chemical. The flocculation of soil colloids is incidental to the main rôle of creating conditions favourable for the bacterial synthesis of active humus. The inhibiting action of lime on the decomposition of organic matter that has been postulated by some investigators to account for the high humus content of chernozems and rendzinas is denied by Gel'tser who states that the accumulation of large quantities of active humus in certain calcareous soil types is connected with the luxuriant growth of grass on these soils and the abundant growth of rhizosphere bacteria on the grass roots that leads to the formation of well-developed humus horizons. The fact that under agricultural conditions the benefits from liming are often not felt until the following year is taken as evidence that the action of lime is biological (stimulation of the bacterial process) rather than physico-chemical (flocculation, base exchange), since in the latter case the effect should be instantaneous. At most a neutral reaction might interfere with the decomposition of lignin. It is known, indeed, that lignin residues comprise a considerable proportion of the organic matter of chernozems, but this fraction is "inert," is not able to combine with the mineral soil, and plays no part in the formation of soil structure.

Taking the increase in the state of aggregation as a measure of the amount of active humus formed, Gel'tser showed that humus formation varies with the intensity of decomposition as well as with the nature of the organic matter, in so far as this affects the rate of decomposition. A podzol and a degraded chernozem were each composted with the same amount of carbon in the form of cellulose, protein and "lignoprotein" (prepared from manure). Decomposition of the cellulose and protein was rapid, and produced a considerable increase in the state of aggregation; decomposition of the lignoprotein was slight and produced a much smaller increase in the state of aggregation. Other experiments indicated that decomposition of lignin was relatively great in podzols, but very slight in serozems, while cellulose was more rapidly decomposed in serozems than in podzols. Thus not only does the part played by different plant constituents in humus formation vary with the soil type, but so also does the type of micro-organisms that effects the synthesis of humus.

Perhaps the main difference between Gel'tser's and earlier theories of the mode of formation of humus is that whereas the latter assume that humus consists largely of the undecomposable residues (lignin) of plants, the former postulates that the primary origin of humus is the decomposable carbohydrates and proteins which serve as a source of energy for the humus-synthesising bacteria. There is, however, no chemical relationship between the starting materials and the product.

Treatment of soils and clays with the products of autolysis, prepared *in vitro*, of certain bacterial cultures gave remarkable results. Thus aggregate analysis of a podzol soil gave 42 per cent. of water-stable aggregates greater than 0.25 mm., and after being moistened with a suspension of autolytic products (containing carbon to the extent of 0.2-0.3 per cent. of the weight of soil) 92 per cent. of aggregates. When the control and treated soils were composted for 21 months the state of aggregation fell to 26 per cent. in the control and to 49 per cent. in the treated soil at the end of the period. Similar experiments on other types of soil gave similar results. No preparations made from decomposing plant residues and free from products of bacterial synthesis had any significant aggregating effect on soils. These had, in general, a peptizing rather than a flocculating effect. Under such artificial conditions of structure formation the humus appears to form an envelope round the soil particles. It does not penetrate into the interior of the aggregate. This constitutes an important difference between the result of adding the humus products of bacterial synthesis to a soil and the result of humus formation *in situ* by the rhizobacteria of growing grass. In the former the humus forms aggregates by enclosing a number of minerals in a cementing envelope, in the latter the humus, besides enveloping the aggregate, penetrates into every interstice and gives it greater stability and probably other different physico-chemical properties. Very little is known of the chemistry of the bacterially synthesised humus. The colloidal products of autolysis exhibit anisotropy, and a crystalline substance believed to be allantoin has been isolated from them. Elementary analyses of one preparation gave 32.5 per cent. ash, 32.9 per cent. C, 7.5 per cent. N, 5.6 per cent. H; or 48.8 per cent. C, 11.2 per cent. N, 8.2 per cent. H on an ash-free basis.

Under natural conditions the formation of a stable soil structure under a grass vegetation depends essentially on the development of rhizosphere bacteria. According to Gel'tser, in the period of growth of the grass, root excretions ensure the development of a populous bacteriorhiza, the products of the biotic activity and autolysis of which impregnating the soil, give it structure. If the grass is subsequently ploughed up, another phase of structure formation occurs after the death of the plants and the absorption of their residues first into the bodies of fungi and afterwards into the bodies of bacteria.

For the efficient performance of these two processes a neutral reaction is necessary. Hence the importance of liming podzol and other acid soils, the fertility of which is being restored by a grass ley. Without lime the decomposition of the plant residues will be delayed at the fungus stage, whereas the formation of stable organo-mineral complexes takes place only after the change from a fungal to a predominantly bacterial process.

For the full development of structure formation in soils, two processes are necessary: firstly, the intensive decomposition of the primary sources of microbial energy, with the resulting synthesis of humus by micro-organisms, and secondly the maximal conservation of this humus by the absence of excessively aerobic conditions. These conditions appear to obtain generally under grass which is thus the ideal medium for the creation of a granular soil structure. Indeed, the main practical object of Gel'tser's work has been to elucidate the mechanism of the fertility-restoring action of grass, this being the pivot around which nearly all applied soil science in Russia now revolves.

'D.D.T.': A NEW INSECTICIDE

BY

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A statement by Government to the public press on recent developments in the application of the insecticidal substance known as 'D.D.T.' and the extensive publicity given in the American press and technical journals to this insecticide have directed attention to a field of work in applied entomology which in peace-time is almost unknown except to the specialists.

With the outbreak of war, and especially when Japan entered the War, the need to protect growing crops and stores of food from insect attack, and above all the need to protect the fighting services from insect-borne diseases, created an unprecedented demand for insecticides. In the face of that enormously increased demand, by the mere entry of Japan into the War, supplies of the important insecticide pyrethrum from that country to the United States were cut off. Worse still, with the loss of Malaya the main source of rotenone derived from *Derris elliptica*, a second important insecticide was lost. The chief, almost the only important source of pyrethrum left to the Allies was Kenya Colony, but its production was unequal to the war demand. A limited supply of rotenone, inferior as an insecticide to that derived from Derris, was available in South America from the plant Lonchocarpus, but again the supply was unequal to the demand. It was in these circumstances, when an urgent and active search for substitutes for pyrethrum and for rotenone was being made, that attention was turned to 'D.D.T.'

'D.D.T.' is a term coined to designate briefly the substance dichloro-diphenyl-trichloroethane, and the term pure 'D.D.T.' designates para-para-dichlorodiphenyl-trichloroethane, which is the most active isomer. In the trade, an insecticide containing 'D.D.T.' as the active ingredient was marketed in the United States as 'Gesarol' and in Great Britain as 'Neocid'. Neither the discovery of the substance itself nor its use as an insecticide is new; but, under the necessity of finding substitutes or near substitutes for pyrethrum and for rotenone as insecticides, new applications or uses for 'D.D.T.' have been developed both in Britain and in the United States.

'D.D.T.' has proved an unusually effective insecticide with more uses than any other single substance so far available, and has already more than justified the intensive work done on its 'development'. For example, it has been used with signal success in Italy—notably in the control of a typhus outbreak in Naples when, in January 1944, 1,300,000 civilians were dusted with 'D.D.T.' powder and within three weeks the outbreak was completely under control. This is the first occasion in medical science when a typhus outbreak has been arrested in mid-winter.

The significance of 'D.D.T.' as an insecticide can best be assessed by comparing it with other insecticides used. Briefly, these are pyrethrum, derived from the flowers of *Chrysanthemum cinerariifolium*; rotenone, derived from the roots of certain leguminous plants, of which species of Derris and Lonchocarpus are the more important; and synthetic insecticides such as the organic thiocyantes and iso-butyl-undecylenamide.

The outstanding feature of pyrethrum is its rapid action, technically described as 'quick knockdown'. Its defects are that, as ordinarily applied as a 'pyrethrum-kerosene' spray, it is

* Reprinted from *Nature*, Vol. 154, No. 3907, 1944.

not persistent, and that to some skins it is irritant, and susceptibility to irritation increases under continued exposure.

Rotenone lacks the rapidity of action of pyrethrum, is not suited for application in kerosene but is more effective as a dust. In this form it is more persistent than pyrethrum and does not cause skin irritation.

The thiocyanates and iso-butyl-undecylenamide more nearly approach rotenone than pyrethrum in their insecticidal action—they lack the 'knockdown' action; they are more toxic to man and animals, and the thiocyanates have a persistent unpleasant odour which quite seriously limits their use.

'D.D.T.', while lacking the rapid action of pyrethrum, has all the good insecticidal qualities of rotenone and the synthetics. In pure form it is practically odourless and it is remarkably persistent. When sprayed on walls at a suitable concentration, 'D.D.T.' kills any fly alighting on them up to a period of three weeks; a bed sprayed with 'D.D.T.' is fatal to bed-bugs for three hundred days, and clothing dusted with it is safe from lice for a month even after several launderings.

In agricultural and in veterinary pest control, as the tests conducted by the U.S. Bureau of Entomology and Plant Quarantine[1] show, 'D.D.T.' also shows high promise.

The truly astonishing rate at which 'D.D.T.' has been 'put through its paces' by the biologists, chemists and malariologists both in the laboratory and in the field, and the extensive demonstration of its value as a general-purpose insecticide, has led in some quarters to the assumption that 'D.D.T. will rapidly replace all the older insecticides, and even to the assumption that much research as, for example, on the methods of testing insecticides, on the relative merits of aerosols and sprays and on the physical and physiological modes of action of insecticides, is no longer necessary. Such assumptions are unwarranted. While on the practical side 'D.D.T.' has provided a solution of our difficulties far beyond expectation, on the scientific side it has raised many problems and difficulties which, while they cannot be fully tackled in war-time, must yet be tackled before the full potentiality of 'D.D.T.' and—this is important—of the methods of using it can be realized. This demonstration of our ignorance of many factors affecting the full use of 'D.D.T.' is bound to react on the development of other insecticides. 'D.D.T.' is not the successful rival ousting all other insecticides from the field. It is a challenge to the chemists and the entomologists to develop these other insecticides by applying to them the same exhaustive and critical study that has been given under pressure of war to 'D.D.T.'. Pyrethrum, for example, is still essential as an ingredient—perhaps with 'D.D.T.'—of sprays designed for the rapid destruction of mosquitoes. When peace returns, the factor of costs both in production and in application will once again become important and rival insecticides will enter the field. One called '666' has already done so.[2]

It should be borne in mind that an important factor in the success of 'D.D.T.' lies in its trial and use on a lavish—by pre-war standards on an extravagant—scale, and until the War ends it will be difficult to see 'D.D.T.' and its competitors in proper perspective.

In looking forward to that time, one may express the hope that the herculean efforts now being made to destroy insect vectors of disease and depredators of our crops and food stores will not be abandoned, as efforts on a lesser scale were abandoned in 1919. During the War of 1914-18, the most widely used specific against lice was a rather crude mixture called 'N.C.I. powder'. It is interesting to note that, according to Professor P. A. Buxton's monograph published in 1939[3], it was still on the active list.

The neglect of applied entomology except in times of crisis has cost us dearly enough; in this present War, but for the efforts of a group of administrators and men of science working in close concert, it might have cost us even more. In the United States, Government departments, university and research institutions and individual workers themselves have described the magnificent effort they have made in this field. In Great Britain, official reticence, if not secrecy, has delayed until now any reference to the equally great effort made by workers in many fields, administrative and technical; industrial and scientific. The co-ordination of that effort and the startingly successful development of 'D.D.T.' was possible only under able and distinguished leadership, both in the military and in the civil branches, and it is to be hoped that in due course that leadership may be acknowledged.

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1. *J. Econ. Entom.*, 37, No. 1, 125 (1944).
2. *Farmer and Stockbreeder*, 58, No. 2847, 688 (1944).
3. "The Louse" (London: E. Arnold and Co., 1939).

SHIFTING CULTIVATION

In a paper submitted to *The Conf. Middle East Agric. Devt.*, Cairo, A. J. Kerr discusses the importance of shifting cultivation as a rational form of agriculture under primitive conditions and the reasons why it breaks down when brought into contact with civilization.

In developing a settled agriculture it is necessary to proceed gradually, and the first step is to control the indigenous form of shifting cultivation. In Uganda this has been successfully done by the use of an alternating grass-fallow strip-cropping system so that fertility is maintained at a high level. This and other steps towards settled agriculture require the parallel development of a system of land tenure that gives security to the holder and allows a definite land policy to be applied. For East African conditions a system of communal or state ownership of land with individual tenancies is suggested as likely to promote progressive agriculture.—(*Soils and Fertilizers*, VII, No. 3, 1944.)

SUGGESTIONS FOR THE USE OF GROWTH SUBSTANCES IN THE VEGETATIVE PROPAGATION OF TROPICAL PLANTS

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Introduction

A major effort is now under way by the Office of Foreign Agricultural Relations to develop methods of increasing rapidly the superior yielding strains of such complementary (non-competitive) crops as rubber, cinchona, derris, and lonchocarpus. Many of these crops are natives of South America and many high yielding strains of these species have recently been found that are superior to present day commercial strains. Cinchona trees have been located which have phenomenal yields of quinine. Lonchocarpus plants have been discovered that have three times the yield of rotenone that is found in roots now on the market. A rapid method of vegetatively propagating these superior strains in order to build up clones available to the commercial growers of these crops is of primary importance in the culture of these tropical crops.

There is also a propagation problem with many other tropical complementary (non-competitive) crops such as cacao, coffee, and tea. Disease-resistant strains have been found which await some method of vegetative propagation before they can be grown commercially.

Work on the vegetative propagation of these tropical plants has been going on for years in the East Indies and Africa but the problems are far from being solved. Much remains to be learned. These plants have been studied only in an exploratory way with growth substances and most of this work was done with 3-indoleacetic acid, which is not the most effective of growth substances now being used in the rooting of cuttings.

Researches in the vegetative propagation of these crops, both by the rooting of cuttings and budding and grafting, are now being actively carried on by agronomists of the Office of Foreign Agricultural Relations and by workers in other organizations concerned with agricultural research in Latin America. The following information on the use of growth substances in vegetative propagation is presented for the convenience of these investigators. Special emphasis is placed on problems which are peculiar to the propagation of tropical plants. No cook-book style recipe can be given for the use of these substances. The concentration requirements vary with the species itself, the type and condition of the wood, method of applying the growth substance, rooting media, and environmental conditions during rooting. The influence of these and other factors are discussed.

Rooting of Stem Cuttings

SELECTION OF CUTTING MATERIAL

Leafy Cuttings: The different species of tropical plants vary greatly in the ease with which they can be rooted from cuttings. Some can be rooted readily from untreated leafless stems stuck in the open field nursery beds. Other species require the presence of leaves on the cuttings before they can be rooted while a third group may require both the presence of leaves plus a growth substance treatment. In general, the growth-substance treatment does not replace the leaf effect; that is, if a certain species roots well from leafy cuttings but not from leafless cuttings, most likely a growth-substance treatment will not give the same beneficial effect as the presence of leaves.

In general, it is recommended that leafy cuttings be tried for most difficult-to-root tropical plants. If such untreated leafy cuttings show any degree of rooting, very likely this rooting can be enhanced by adequate growth substance treatment.

Condition of Wood: The requirements for successful rooting of some species of plants not only include the presence of leaves but also that the wood of the cutting be of a certain physiological condition. In some plants the cuttings should be made of soft green wood taken from a flush of new growth. Other plants such as citrus seem to root best from mature hardwood terminal growth (Cooper 1940).

Many plants, however, appear to fall in an intermediate stage known as semi-hardwood. Cacao is a species of the intermediate class. Pyke (1932) has shown that this species has very exacting requirements as to maturity of wood for successful rooting. Shoots actually in the act of making a flush of new growth were not particularly suitable, as they frequently rot and die back. Fully mature shoots, on the other hand, carry senile leaves which readily abscise. The best stage was immediately at the end of a flush of growth, when the leaves are fully expanded, but still quite young.

Cuttings with considerable pith in the stem are as a rule difficult to hold in good condition in the propagating frames. They are particularly susceptible to decay as they do not form callus tissue readily over the pithy area. If such material has to be used it is always a good practice to make the basal cut at a node where there is likely to be less pith.

It is important to point out that these requirements for condition of wood are just as essential for growth substance treated cuttings as for untreated cuttings. The use of growth substances does not make it possible to root cuttings of all plants at any time of year and under any condition. Greatest success with growth substances has been obtained under conditions and with types of cuttings which the old-time propagator would class as definitely favourable.

Latex: In cuttings of latex-bearing plants, the latex may be bothersome since the basal cut may become plugged with the exudate. One treatment for this consists in washing the cut surface repeatedly until no more latex exudes. Another treatment employs dipping the base in a dilute water suspension of charcoal and gum arabic which is allowed to dry on the base of the cutting. Simply dipping in powdered charcoal has been used for poinsettia cuttings.

Juvenility: An understanding of the distinctions between the juvenile and mature stages of growth in plants may be an aid to the rooting of cuttings of many hard-to-root plants. The work of Gardner (1930) on the rooting of stems from young seedlings of woody plants suggests that all seedlings pass through distinct juvenile and mature growth phases. The juvenile condition was recognized in the apple by thinness of leaves and small amount of pubescence. In other species of plants the shape of the leaf may change but quite often the different phases of growth are not always visible to the eye. The literature shows that the juvenile growth phase may change to the mature form gradually through a series of transitional stages. In young seedlings the first noticeable change often occurs immediately after the first period of dormancy.

The important physiological difference from a propagation standpoint between stems in the two growth phases is that stems in the juvenile phase are always easier to root than those on the mature growth phase regardless of the presence or absence of visible differences in the character of the growth. Gardner (1930) demonstrated this with the apple and a variety of deciduous and coniferous tree species. It has since been found true with the avocado (Eggers and Halma, 1937), with certain coniferous plants (Thimann and Delisle, 1939), and with a number of subtropical fruits (Gardner, 1942). With many of these plants the growth substance treatment will stimulate the rooting of cuttings of twigs in the juvenile growth phase but will not induce rooting on twigs on the mature growth phase.

The rooting of cuttings from young seedlings may be used advantageously in a breeding programme where it is important to have two or more plants of any particular progeny. Loomis (1942) doubled the number of small plants of *Hevea brasiliensis* by splitting the young seedling. Making cuttings of the stem of the young seedlings would accomplish the same thing.

As a rule, however, the practical horticulturist is more likely to be interested in rooting cuttings from mature trees, the performance of which he may know something about, than he is in rooting cuttings of young seedlings. For instance, the tropical horticulturist working on cinchona is greatly interested in rooting cuttings from mature trees which are known from bark analysis to contain large amounts of quinine.

Accordingly, the practical horticulturist will be greatly interested in methods of inducing juvenile growth on mature trees. Stoutemyer (1937) has developed a method of inducing juvenility in apples that is promising from a practical standpoint. He found that shoots grown from adventitious buds on a young, active root showed juvenile characteristics and stem cuttings made from these shoots formed roots readily.

In addition to obtaining juvenile growth from adventitious buds on roots, there is also a possibility of obtaining juvenile shoots from near the base of older trees. This is based on the view that the root system and the lower portion of the plant tend to remain in the juvenile condition after other parts have passed into a mature type of growth. In considering this method of inducing juvenile growth a clear distinction must be made between grafted trees and seedlings. In grafted trees the scion is ordinarily made from wood of shoots in the mature growth phase, no part of the scion ever having passed through the juvenile phase. In the case of the seedling the wood at the base was originally in the juvenile stage of growth and the juvenile condition might possibly persist at the base. Thus growth from nodal buds near the base of seedlings may be in juvenile form.

There is also the possibility that juvenile growth may develop from adventitious buds on the limbs of mature trees. In the apple, however, adventitious buds were seldom induced. Water-sprouts resulting from heavy pruning in the apple ordinarily did not originate from adventitious buds but from latent buds. Watersprouts exhibited only the external characters of mature growth and cuttings made from them ordinarily did not root. This condition may not, however, be the case in all plants and heavy pruning to induce juvenility should be tested, particularly cutting back to secure stump sprouts, when practicable.

Propagation Facilities

Frames: The use of leafy cuttings requires the employment of propagating facilities that will maintain a nearly saturated atmosphere around the leaves of the cuttings and at the same time provide light. The ideal facility meeting these requirements would be an open propagating bench in a humidified green-house. Such equipment, however, is not readily available in many of the tropical experiment stations, therefore, propagation frames with glass lids are primarily relied upon to provide these conditions.

There are many different types of frames now in use. For temporary purposes one constructed of wood with a glass lid is satisfactory. For

permanent use one constructed of concrete is preferable. The I.C.T.A. propagator developed at the Imperial College of Tropical Agriculture at Trinidad, B.W.I., is a very effective frame of the permanent type (Cheesman and Spencer, 1935). It is a concrete bin of the following dimensions:

Length	...3 feet 0 inches
Width	...2 feet 6 inches
Height of back wall	...3 feet 0 inches
Height of front wall	...2 feet 10 inches
Thickness of walls ...	... 4½ inches

For convenience, these frames are built in blocks of 12, arranged back to back in two rows of six. The lids are made of glass sash and may or may not be hinged.

Drainage is provided by means of stones at the bottom of the frame to the depth of about 2 feet. The largest stones should be at the bottom and they should gradually diminish in size until finally there is merely a layer of pebbles on top. This will provide a good base for about 6 inches of the rooting medium.

The bins are provided with a canopy of calico which furnish the sides, ends and top of the propagator with shade at all hours of the day and at all seasons of the year.

The glass lids are covered with a double layer of cheesecloth which, combined with the calico canopy, gave the right amount of shade for leafy cacao cuttings (Cheesman and Spencer, 1935). The shade may be varied to suit the plant by using more or less cheesecloth. The cheesecloth is kept wet during the day and the evaporation from it cools the air in the interior of the propagator by as much as ten degrees Fahrenheit. This is a decided benefit to enclosed covered propagators in the tropics, as the air temperature surrounding the leaves on the cuttings frequently rises to near 100°F. The high temperature is injurious to the leaves and also makes it difficult to maintain a high humidity in the frame.

When leafless cuttings are used it is not necessary to use any of the above-mentioned propagating facilities. Shaded and well drained nursery beds are frequently used for such material.

Rooting Media: Sand is the most frequently used rooting medium, as it requires less skill in watering. Sharp sands are preferable, both coarse and fine grades being satisfactory if watered properly. The coarse sands require more frequent watering than the fine sands. The latter will pack if watered too often, and may not give adequate aeration.

A fine quartz sand is preferable for rooting most plants. Beach and river sands loaded with calcareous material are generally considered injurious to good root formation on many plants.

Mixtures of sand and peat frequently aid root formation. This is particularly true for cuttings of most ericaceous plants. The advantage of acid peats is that they have a high buffering capacity and maintain a low pH. The use of peat in rooting media demands more care in watering than sand.

Fernie (1940) has found that coffee cuttings root well in a mixture of 2 parts peat to 1 of coarse sand but shows no data for rooting behaviour in coarse sand without peat.

Proportions for mixtures of sand and peat vary widely. They usually run around 75 per cent. sand.

Peat moss is expensive and may be unavailable in many tropical localities. In such cases various plant residues available in those localities may be substituted for peat moss. Such materials as sago fibre, coconut fibre, leaf mould, sawdust, peanut shells, charcoal, and pine needles have been used with varying success. Fernie (1940) reports that coconut fibre and leaf mould can be substituted for peat in the rooting of coffee cuttings but that rooting often takes longer where these materials are used.

Too much emphasis cannot be placed on the value of good drainage and aeration in the propagating medium. Many propagating failures are due to poor drainage. The use of a frame such as the I.C.T.A. propagator insures good drainage to the rooting media.

The continued use of alkaline water may also cause difficulties in rooting. Likewise the use of chlorinated tap water with exceptionally high chlorine content often had deleterious effects on rooting. In such instances it is best to collect rain water to use for watering the cuttings.

Methods of Application of Growth Substances

Lanolin Paste: In the early growth-substance experiments the method of treatment consisted in applying a paste of the growth substance dissolved in lanolin to the cuttings (Cooper, 1935). A small portion of 0.05 per cent. growth-substance lanolin paste was smeared onto a small area of the cutting near the top which had previously been scraped to remove the epidermis and outer cortical layers.

This method of treatment, although used a great deal by the early workers in this field, has now been outmoded by much more effective methods.

Dilute Water Solution Soak: Soaking the base of the cuttings in dilute water solutions of the growth substances for periods ranging from 6 to 48 hours is a very effective method of treatment and has been used extensively on thousands of species of plants. The method was discovered simultaneously by Hitchcock and Zimmerman (1936) and Cooper (1936).

The solutions are prepared by dissolving the growth substance in a few drops of ethyl alcohol and then diluting with water to the required concentration. The basal ends of the cuttings were placed in beakers containing the minimum amount of the test solutions required to cover about one inch of the stem. The duration of the treatment is adjusted to the concentration of the solution since a longer period of time will, within limits, compensate for a lower concentration of growth substance.

In general practice, however, a standard 24 hour treatment is usually followed and the concentration of the solution is adjusted to the requirements of the cuttings being treated. These requirements

vary with the plant species, with the type of material selected for the cuttings, and the growth substance used. Concentrations ranging from 0.01 to 0.5 mg. per ml. have been used successfully on various plants. In general the highest non-toxic concentration will give the best results. It is usually, but not always, lowest for greenwood cuttings. Recommendations for tropical plants include 0.1 mg. per ml. 3-indoleacetic acid for coffee (Gillette and Jackson, 1937), 0.2 mg. per ml. 3-indoleacetic acid for citrus (Cooper, 1940), 0.1 mg. per ml. 3-indolebutyric acid for derris (Cooper, 1944).

In treating leafy cuttings by this method, it is usually best to place the cuttings in the sash-covered propagating frame during the soaking period as it is easier to control the treatment under high humidity conditions. Under dry conditions where the leaves are transpiring rapidly, too much of the test solution may be absorbed and cause injury to the cuttings. Also with leafy cuttings of some tropical plants, such as cacao, a 24 hour period under low humidity conditions will invariably cause all of the leaves to abscise.

Talc Dip: Since its first use by Grace (1937) the talc dip treatment has been the most popular method of treating cuttings with the growth substances. The method consists in simply dipping the moistened base of the cuttings in the talc-growth substance mixture to the depth of about one-half inch. This technique has the advantage of ease of application and its effectiveness is virtually as great as is secured with other methods (Stoutemyer 1939 and Hitchcock and Zimmerman 1939).

The talc-growth-substance mixtures may be prepared by a grinding mix in a mortar by hand, or in a ball mill. Stoutemyer (1939) prepared the mixtures by dissolving the growth substance in 95 per cent. ethyl alcohol and this solution was then stirred into talc to make a pasty mixture. The preparation was then dried and stirred occasionally during the drying period.

The physical characteristics of the talc, particularly the fineness, has been found to influence the effectiveness of the preparation (Hitchcock and Zimmerman, 1939). The more a given preparation is ground, the more effective it is likely to be. Thus, a given concentration of growth substance may give a variety of results depending on what kind of talc is used, how it is prepared and how long and vigorously it was ground if prepared by the grinding procedure.

Because of their convenience many investigators prefer to use commercial preparations of talc-growth-substance mixtures. There are several different brands on the market and they come in various concentrations of growth substance with recommendations for use. These commercial preparations have given results not significantly different from those secured from laboratory mixtures (Poesch, 1938, and Tincker, 1938).

Results differ as to the stability of the talc-growth substance powders. Kirkpatrick (1940) reports that one-year-old powder preparations exposed to the air in a green house and used continually throughout the year were as effective in rooting as freshly prepared powders. On the other hand, Stoutemyer (1941) has found that talc preparations when exposed to moisture undergo a slow deterioration, as indicated by a decrease in their effectiveness in causing rooting. Cooper (1944) obtained results similar to Stoutemyer with both laboratory-made and commercial powders during a nine months period in Puerto Rico. The powders were stored in clear glass-stoppered bottles in the laboratory.

From these results it would appear best to play safe and store the powders in a dry place and in sealed containers.

Since the procedure of treating the cuttings requires that the bases of the cuttings be wet before dipping in the powder, it is a good practice not to dip the cuttings directly into the stock container of powder as this procedure might contaminate the entire stock with water. Pour from the stock bottle into a separate container the quantity of powder that is needed for any particular series of cuttings and never return the used powder to the stock bottle. It is also advisable to replace the stock supply of powders every year with fresh preparations.

In numerous experiments at Glenn Dale, Maryland, Stoutemyer (1939) has found the concentration of one milligram of growth substance per gram of talc to be useful with a wide variety of cuttings but a concentration of 4 to 12 milligrams per gram was needed for the difficult-to-root subjects. This method of treatment has not been used extensively on tropical plants.

Concentrated Solution Dip: This method, which involves a quick dip in solutions containing from 0.5 to 10.0 mg. per ml. of growth substance, is highly effective and has the advantages of the solutions being easy to prepare and easy to apply. It was first reported by Hitchcock and Zimmerman (1939) and was found by these investigators to be equally effective as the other methods of treatment. Recently Cooper (1944) used the method successfully in the rooting of derris, lonchocarpus, cinchona and cacao.

The solutions are prepared by dissolving the growth substance in 95 per cent. alcohol and then diluting to the desired final volume with tap water. The volume of alcohol used depends on the desired concentration of alcohol. In most instances 50 per cent. alcohol has been used. However, varying the alcohol content from 0 to 95 per cent. had very little influence on the effectiveness of the solutions (Cooper, 1944).

Treatment of the cuttings with the concentrated solutions merely involves a momentary dip (one second is sufficient (Cooper, 1944)) of the basal ends of the cuttings into the solution. The method in addition to being more rapid than the soaking technique, also requires less glassware and table space. One glassful of the concentrated solution can be used to treat a thousand cuttings in about 15 minutes.

The solution dip also has a slight advantage in ease of treatment over the powder dip technique. When the base of bundles of cuttings is dipped into a liquid solution, there is likely to be a more uniform distribution of the solution throughout all the cuttings of the bundle than is possible with a dip into talc dust.

Equivalent rooting by the dip treatment usually requires nearly 25 times the concentration by weight of growth substance used in the soaking method. This, however, does not necessarily make the method more expensive to use because by the dip treatment the same solution can be used over and over many times in a brief period without losing its effectiveness. For instance, in an extensive experiment with derris, the same 100 ml. of 5 mg. per ml. solution was used 25 different times in the period of an hour in treating 2500 cuttings, 100 cuttings being dipped at a time. To treat this same number of cuttings by the dilute solution soaking method would have required the use of approximately 2500 ml. of an 0.2 mg. per ml. solution, or 500 mg. of growth substance which was the same weight required by the concentrated solution dip method.

Suggested concentrations of growth substance to try on cutting of tropical plants are 0.5 to 5.0 mg. per ml. Cacao, derris, and cinchona rooted well when dipped in a 2 mg. per ml. solution of 3-indolebutyric acid (Cooper, 1944).

Effectiveness of Different Growth Substances

Response of Different Species : Of the substances which are known to have root-forming activity, 3-indoleacetic acid, 3-indolebutyric acid, alpha-napthaleneacetic acid, and alpha-napthaleneacetamide are the most useful for practical propagation work. Of these, 3-indolebutyric acid is definitely more effective on most species than is 3-indoleacetic acid. Among the exceptions are *Pyracantha coccinea* and *Lonicera korolkowii* (Poesch, 1938), mountain laurel (Skinner, 1938), and honey locust (Stoutemyer, O'Rourke, and Steiner, 1944), all of which gave a better response to 3-indoleacetic than to 3-indolebutyric. Also with most varieties of citrus Cooper (1940) obtained equal rooting from 3-indoleacetic and 3-indolebutyric. There are, however, a great number of plants that give no response to 3-indoleacetic acid while 3-indolebutyric is highly effective. *Derris elliptica*, var. Sarawak Creeping, and *Lonchocarpus utilis*, clones A and C at the Puerto Rico Experiment Station, are examples of tropical plants that show no response to 3-indoleacetic acid but respond readily to treatments with 3-indolebutyric acid (Cooper, 1944).

Indolebutyric acid is also probably more effective than alpha-napthaleneacetic acid for cuttings of most species although the latter is quite effective on many species. In the cases of black locust (Stoutemyer et al, 1940) oriental bittersweet (Hitchcock and Zimmerman, 1938), *Deutzia scabra* (Grace, 1937), species of privet (Hitchcock and Zimmerman, 1939), and yew (Kirkpatrick, 1939), cuttings have responded more to treatments with alpha-napthaleneacetic acid than to 3-indolebutyric acid. Generally, alpha-napthaleneacetic acid has been found to have a more narrow range of effective concentration than 3-indolebutyric acid, more care being required in the use of the former to prevent injury to the cuttings.

Alpha-napthaleneacetamide is generally less toxic than the acid and is fully as effective as the acid on many plants (Stoutemyer, 1939a) and for this reason has considerable value. One disadvantage of the amide is its relative insolubility, it being hard to prepare water solutions concentrated enough to induce root formation. This, however, can be overcome by the use of the talc dip and the concentrated alcohol solution dip methods in place of the water solution soaking procedure.

Mixtures of Growth Substances : Hitchcock and Zimmerman (1940), taking cognizance of the fact that various species respond quite differently to different growth substances, mixed the substances in equal proportions and found the mixtures were generally more effective on more subjects than either alone. Mixtures of 3-indolebutyric acid and alpha napthaleneacetic acid were particularly effective and such a mixture is highly recommended for work with species of plants which have not been tested.

Recently a 2, 4-dichlorophenoxy-a-butyric acid and other phenoxy derivatives have been reported by Zimmerman and Hitchcock (1943) to be effective in root formation in concentrations 10 to 100 times lower than any of the above compounds. These compounds, however, are difficult to use without causing injury to the cuttings and at present are used mainly in mixtures of the other growth substances in the ratio of 1 part phenoxy compound to 9 parts of the other.

Supplementary Treatments

Re-treating with Growth Substance : Cuttings which have not rooted when removed from the propagating bench may be induced to root by a second treatment without removing the callus. Re-treatment of cuttings of papaya, camellia, and sweet orange were induced to root when an initial treatment gave no response (Cooper and Went, 1938).

Stuart and Marth (1938), working with holly cuttings showed that a deferred growth-substance treatment to 76-day-old untreated cuttings which were heavily callused induced vigorous rooting within 21 days. Thus it is seen that a growth-substance treatment is often effective on unrooted cuttings that have failed to root regardless of whether or not they received an initial growth substance treatment.

In case of hard-to-root cuttings for which a suitable concentration is not known, a safe procedure to follow would be to employ a relatively low concentration for the initial treatment and, if the cuttings fail to root within a reasonable length of time, re-treat, using a higher concentration.

Wounding or slitting the bark at the base of the cutting before placing in solutions of growth substances has been shown by Stuart and Marth (1938) to induce a greater number of roots on holly cuttings than was obtained on unwounded but growth substance treated cuttings. Amlong and Noundorf (1938) obtained similar results with citrus. Probably the main advantage is due to a greater intake of the solution but some may be due to the action of a wound hormone. (Mitchell et al. 1942).

Recently a wound substance, traumatin, has been isolated and synthesized by English and Bonner (1937). Mitchell et al. (1942) have reported increases in rooting of cuttings of the difficult-to-root species, *Pinus caribaea*, following applications of traumatin (0.05 mg. per ml.) in conjunction with a combination treatment of growth substance (a commercial dust preparation), sucrose (5 percent.), vitamin B_1 (0.01 mg. per ml.) and a complete mineral nutrient solution. He, however, did not give data to showt hat the traumatin had any effect on the rooting. Stoutemyer (1944) has found that the concentration of traumatin used by Mitchell et al produced toxic effects on succulent material.

Mineral Nutrients: Grace and Thistle (1939) and Grace (1939) report some evidence that treatments with mineral nutrients used in conjunction with growth substance promoted better rooting than growth substance alone. Weekly applications of Hoagland's nutrient solution to the sand increased the number of rooted cuttings as compared with those not receiving the nutrient. All cuttings were given the same growth substance treatment. The plants used were *Lonicera tatarica* and the Norway spruce.

Other experiments (Grace and Thistle, 1940) in which talc dusts containing nutrients salts in combination with growth substance were used, produced no increase in percentage rooting over growth substance alone but did cause an increase in root length.

Researches on the use of nutrients are too limited to permit adequate evaluation of their practical value in propagation.

Amino Acids: Doak (1939) found that a supplementary treatment with a mixture of amino acids was highly effective on rooting of growth substance treated cuttings of *Rhododendron maddeni* var. *jenkinsii*.

One hundred per cent. of the cuttings treated with growth substance plus amino acids rooted after six weeks, while no rooting occurred on cuttings receiving only the growth-substance treatment. The amino acid mixture consisted of 5.0 mg. per litre glutamic acid, 1.5 mg. per litre lysine, 1.5 mg. per litre histidine, 1.5 mg. per litre phenylalanine, 0.015 mg. per litre leucine, 0.0015 mg. per litre isoleucine, 0.15 mg. per litre valine, 0.05 mg. per litre serine, and 0.5 mg. per litre proline. The best amino acid treatment was soaking the base of the cuttings for a week in this solution. However, soaking for only 24 hours in a solution 10 times as concentrated as above gave 60 per cent. rooting.

In later investigations Doak (1940) showed that amino acids were not necessary to obtain this increase in rooting response and he produced a similar effect with ammonium sulphate and to a somewhat lesser degree, with sodium nitrate. Other nitrogenous compounds such as the purine bases were effective, and adenine, guanine, xanthine, caffeine, uric acid, and alloxan were ranked in increasing order of effectiveness. Betaine was likewise highly potent. The order of effectiveness was apparently correlated with the number of nitrogen atoms in the molecules. Doak explained the occasional superiority of the indole growth substances over the naphthalene compounds to the inclusion of nitrogen in the ring.

Thimann and Poutasse (1941) likewise found that both survival and rooting of cuttings of *Phaseolus vulgaris* were improved by treatment with potassium nitrate, adenine, or asparagine, and to a lesser extent by some other nitrogenous compounds. However, ammonium sulphate and likewise calcium and magnesium salts at the concentrations used in nutrient solutions inhibited rooting.

Vitamins: It has been demonstrated that vitamin B_1 (Bonner and Addicott, 1937), vitamin B_6 (Robbins and Bartley-Schmidt, 1938) and nicotinic acid (Bonner and Devirian, 1939) are essential substances for the growth of excised roots *in vitro*. From these results it was deduced that vitamin treatments might possibly aid in the growth of roots on cuttings. In general, however, investigators have not found such effect, although occasionally positive responses are recorded. Higher plants appear to have the capacity to synthesize their own growth factors of this type in sufficient quantities. Considerable published and unpublished evidence has established that practical value of promiscuous vitamin application to cuttings is without general merit.

Sugar: It is generally known that the production or roots (or any other growth) requires carbohydrate. Most cuttings of green plants contain ample carbohydrate and appear not to be dependent on added sugar for rooting. However, under certain circumstances some cuttings may require added sugar. Leafless cuttings are more likely to require added sugar than leafy cuttings, as the latter have the facility for continued photosynthesis in the propagating frame if adequate light is provided.

The problem of sugar in root formation on growth substance treated cuttings has not been adequately studied. It is known from the investigations of Stuart (1938) and Mitchell and Stuart (1939) that there is a movement of carbohydrates to the base of the cuttings following the growth substance treatment where it is utilized in the production of roots. In leafless cuttings a carbohydrate starvation might be induced in the plant following such a treatment as there are no leaves to produce more carbohydrate. This would be more likely to happen where a growth substance treatment induced an excessive number of roots as in the case

of experiments conducted on leafless derris cuttings by Cooper (1944a). In these experiments the treated leafless cuttings showed poor root growth after the roots were formed while treated leafy cuttings showed excellentro ot growth. Theoretically, one might deduce that an application of sugar to the leafless cuttings would be beneficial. Actually, the use of a 2 per cent. sucrose solution in connection with treatments of leafless hardwood cuttings of black locust was observed to aid both the survival and subsequent growth. (Stoutemyer, Jester and O'Rourke, 1940).

Other Effects of the Growth Substance Treatment

Anatomical Changes: The first visible effect of the growth substance treatment is usually a slight increase in thickness of the base of the cutting. In lemon cuttings this swelling of the base was observed within six days (Cooper, 1938). Histological examination showed that a wide band of meristematic cells, apparently resulting from a proliferation of the cambium appeared between the phloem and xylum within 2 days. This region usually developed into a band of about 25 cells within 6 days. At that time some of these meristematic cells had differentiated into root primordia.

Stuart (1938) observed the same rapid swelling of the base of treated kidney bean cuttings prior to the production of roots. Kraus, Brown, and Hamner (1937) and Hamner and Kraus (1937) show that in the kidney bean the growth-substance treatment not only stimulates activity of meristematic cells of the cambium but also the mature vacuolated cells of the cortex, endodermis, phloem, medullar rays, and pith. In these mature cells, the first detectable change was the disappearance of starch, accompanied by an increase in the density of the cytoplasm, an enlargement of the cells, cell division, and finally differentiation into various types of cells such as root primordia.

Callus Formation: The growth-substance treatment may not only induce a swelling and cambial activity in the stem just above the basal cut surface of cuttings but also may stimulate callus formation at the basal cut surface. This callus formation appears to be due to proliferation of cortical parenchyma and medullary ray cells as well as to cambial activity. (Sass, 1932 and Sharples and Gunnery, 1933).

In general, it has been found that cuttings treated by the lanolin-paste technique will induce more callus but fewer roots than the water solution soaking method. Thus the formation of callus at the base is not necessarily associated with good rooting.

The only quantitative work reported on callus formation on cuttings is that of Rogenhofer (1936). He determined the callus produced on sections of *Populus* twigs by separating and weighing it. The amount of callus formed by 3-indoleacetic acid decreased rapidly with distance from point of application, approaching zero at about three cm. below it. The strongest callus followed application of .001 per cent. 3-indoleacetic acid, lanolin paste to the cut end.

Bud Inhibition: A temporary inhibition of the buds of a cutting is frequently noticed when growth substances are applied in concentrations high enough to produce abundant root formation. The naphthalene compounds are more effective in this respect than are the other compounds. The phenyl compounds, which are slightly effective in root formation, are completely inactive in bud inhibition.

There is no evidence at present that this type of bud inhibition interferes with the formation of roots. It may, however, have a detrimental effect on root elongation if bud growth is delayed too long. This was particularly true with growth-substance-treated leafless derris cuttings (Cooper, 1944a). Roots were formed after two or three weeks but buds were inhibited for four to six weeks. The roots began to die back at the end of six or eight weeks. Leafy cuttings, on the other hand, induced as many or more roots but buds were not inhibited quite as long. The roots grew vigorously.

Chemical Changes: The first apparent change in the cutting after growth substance treatment is that reserve carbohydrates in the form of starch are made available through hydrolysis (Mitchell and Whitehead, 1941). Sugars and inorganic substances are transported from the leaves and tops of the cutting to the treated base (Stuart, 1938). These materials are rapidly utilized in the production of new cells at the base, and eventually their maturation and differentiation into root primordia and other kinds of cells. The utilization of food in the production of a great number of roots at the base is so great that relatively large amounts of these materials move from other parts of the plant to the lower region (Stuart, 1938).

In treated leafless cuttings this movement of the food reserves from the apex of the cutting to the base might possibly exhaust the food reserves at the apex, there being no leaves present to replenish the supply of these materials. Since the production of new shoot growth also requires carbohydrates, prolonged inhibition of this new shoot growth may in part result from the mobilization of food materials away from the bud. Mitchell (1942) expresses the same view.

Toxic Effects: Over-treatment of the cuttings with excessive concentrations of growth substances is manifested in a number of different ways. The most obvious signs are excessive swelling and proliferation at the base, killing of the lower part of the cutting, and the production of an excessive number of short roots. Another less obvious sign is too few or in some cases no roots, when lower concentrations will induce a large number of roots.

It is well to be on the look-out for all of these signs of over-treatment as such treatments have ill after-effects on the plant. The growth of the cuttings may be stunted and in some cases the

whole series of cuttings will die. Experiments conducted with a logarithmic graded series of concentrations are recommended as a means of determining the optimal treatment.

Effect on Subsequent Growth of Cutting: It is of considerable practical importance to know if the propagation of cuttings with appropriate concentrations of growth substances affects materially the subsequent growth and behaviour after rooting. The rapid and heavy rooting induced by the treatment gives the cuttings an initial advantage, but there is no convincing evidence to show that this is maintained throughout the life of the plant. In fact, Mitchell and Stuart (1939), using increases in dry weight as an index of growth, found that initial stimulating effects of the treatment on growth tend to diminish during subsequent vegetative development of the plant until finally little difference exists.

With derris cuttings there was a large increase in dry weight of roots on treated cuttings as compared with controls during the first three months but after six months the weight of roots was about equal for both treated and untreated cuttings. There were many more roots on the treated than on the untreated cuttings but the size of the individual roots was much greater for the untreated plants.

Value of the Growth Substance Treatments

Among the least debatable advantages resulting from the use of appropriate growth substance treatment are: (1) The increased number of roots on treated cuttings is an aid to the successful transplanting of cuttings from the propagating frame to the nursery. (2) The reduction in time of rooting, which is sometimes nearly half, will often result in a measurable economy of time and space of propagating facilities. (3) An increased percentage of rooting can be expected on cuttings moderately hard to root such as oranges and cacao (Cooper 1940, 1944). (4) Some plants which are rarely rooted successfully without growth-substance treatment can be rooted by the aid of the treatment. There are still many plants, however, such as the avocado and mango, which cannot be rooted successfully by the growth-substance treatment.

Rooting of Other Types of Cuttings

Root Cuttings

The practical use of growth substances for rooting root pieces has not been extensively investigated. From the few experiments conducted on root cuttings it appears that the general effect of the treatment is the same as on stem cuttings; *i.e.*, to inhibit bud development and stimulate root development. However, more care has to be exercised in the growth-substance treatment to induce adequate rooting without preventing excessive bud inhibition.

Marth and Hamner (1943) have used growth substances effectively in rooting root pieces of *Taraxacum kok-saghyz*. They treated root cuttings with 3-indolebutyric acid, alpha-naphthaleneacetic acid, alpha-naphthaleneacetamide, and beta-naphthoxy-acetic acid; alone and in mixtures. With all substances, soaking for 16 hours in water solutions having a concentration of 50 mg. per litre was optimal and all were injurious at 100 mg. per litre. Eighty-seven per cent. of the 3-indolebutyric acid series, 77 per cent. of the alpha-naphthaleneacetic series, 70 per cent. of the alpha-naphthaleneacetamide, and 73 per cent. of the beta-naphthoxy-acetic acid series developed into plants as compared to only 40 per cent. for the water controls.

Leaf-bud Cuttings

The leaf-bud technique consists of taking a bud with a single leaf attached, just as though it were to be used in shield budding. The bud is inserted in sand so that the shield of wood is just covered and the leaf is in the air above the sand.

Watkins (1940) used the method with favourable results in rooting *Bougainvillea spectabilis* var. Crimson Lake, *Cocculus laurifolius*, *Codiaeum variegatum*, *Hibiscus rosa-sinensis*, *Ipomoea fistulosa*, *Ixora coccinea* and *Thunbergia grandiflora* var. *alba*. Leaf-buds of each of these species formed heavier root systems more quickly when treated with a 5 mg. per gram 3-indolebutyric acid-talc mixture than did comparable untreated leaf-buds. All of the material made satisfactory growth and developed into normal plants.

Cooper (1944a) rooted leaf-buds of *Lonchocarpus utilis* successfully with or without the growth-substance treatment, there being no difference in the root system produced.

In tropical agriculture, its greatest application is in cases where there is a scarcity of a particular propagating material. In the instance of a superior yielding lonchocarpus plant, every mature leaf-bud in the top of the plant could be propagated by this method.

Marcottage

Marcottage or air layerage, has been used from time to time in the vegetative propagation of lychee, cacao, cinchona, and lonchocarpus. Cooper (1944) showed that a growth-substance treatment can be used effectively in increasing the rooting of marcots of cacao and cinchona. In these experiments the branches being marcotted were first girdled and then the girdle and a small region above the girdle was painted with a 50 per cent. alcohol solution of 5 mg. per ml. 3-indolebutyric acid. Then moist sphagnum moss was tied around the girdled and treated region. This treatment increased the percentage of successful marcots on cacao from 16 per cent. to 66 per cent. and on cinchona from 0 per cent. to 100 per cent.

Healing of Wounds

The studies on the use of growth substances in the rooting of cuttings have shown that these substances also stimulate cambial activity and induce callus formation at the base of the cutting. Shear (1936) was the first to report observations on

the effect of the growth substances on the healing of tree wounds. He tested the effect of an 0.5 per cent. 3-indoleacetic acid-lanolin paste on callus formation on wounds of terminal shoots of apple, maple and linden. No increased callus formation was induced over that obtained from treatment with pure lanolin. Jakes (1938), two years later, tried a one per cent. 3-indoleacetic acid-lanolin paste on wounded areas of terminal shoots of peach, plum, apple, and pear and reported the treatment effective in healing the wounds. The control wounds produced only a small amount of callus at the edges of the wound and none away from the edges, while the treated wounds produced a heavy callus not only at the edges of the cut bark but also in independent centres over the entire wound surface.

Data on this general subject are too meagre at present to account for the differences in results obtained by Shear and Jakes. A large-scale investigation, including tests on various concentration of growth substances applied with different carriers on a number of different types of wounds, is needed to elucidate this subject. The healing of an unprotected wound with injured wood surface, as where a branch is cut off, might require different treatment from a wound where only a strip of bark is peeled off. In the latter type of wound such as in the experiments of Shear and Jakes, the meristematic surface of the wood is preserved intact.

Grafting and Budding

A graft union is essentially a healed wound and growth substances would be expected to play the same rôle in proliferation of a callus across a graft union as across a wound surface. However, very little investigational work has been done in this field and much of that which has been done deals with varieties of grapes.

Kordes (1938) immersed stocks and scions of grapes for 16 hours in a 0.01 per cent. water solution of 3-indoleacetic acid, then grafted, and stored in moist sawdust for a period before lining out in the field. The treatment was effective in increasing both the rooting of the stock and in the callusing of the graft union.

Muller-Stoll (1939) working with grapes, likewise found a 16- to 24-hour immersion treatment advantageous and obtained excellent results by a quick dip in a concentrated 3-indoleacetic acid solution. He also found that dabbing the cut surface of the stock and scion with 3-indoleacetic acid solutions increased the percentage of successful graft unions.

Lefèvre (1939), working with grapes, found that soaking the cut ends of the stock and scion for 48 hours in .01 per cent. 3-indoleacetic acid aqueous solution was preferable to soaking the whole graft for the same period. He reported that 3-indoleacetic acid gave better results than 3-indolebutyric acid.

These workers with grapes pointed out that frequently the scions as well as the stocks rooted as a result of the treatment. Since the scions were quite susceptible to phylloxera, the rooting of the scions was a distinct disadvantage.

Evenari and Klonis (1938) reported beneficial results on apple graft but not on cherry or pear. They called attention to ill effects from the treatment when the growth substances are applied directly to the graft union because such treatment often caused excessive proliferation which tended to push the stock and scion apart.

These relatively few reports of investigations on the aid of growth substances in grafting indicate both desirable and undesirable effects of the growth substance treatment. More extensive trials with a variety of plants should be made. Since it is known that the growth substance is transported basipetally through the phloem tissue of the stem and will induce callus formation at a wound some distance from the point of application, applying the growth substance to the apex of the scion appears to be a good method of treatment. It will avoid excessive callus formation that may result when applied directly to the cut surfaces of the graft union.

Applying the growth substance by the lano in-paste technique, if found successful, would be a more practical method of treatment than the water soaking method. Also the method of a quick dip of either the apex or base of the scion piece in a concentrated alcohol solution of growth substance should be tested. However, it is suspected that a more dilute lanolin paste treatment will be more effective for callusing.

There is little evidence available on the use of growth substances as an aid to budding. A possible disadvantage of the treatment would be excessive bud inhibition. Perhaps a treatment of the stock by the lanolin paste technique at some point above the bud would be the logical treatment. This should induce callus formation in the stock at the wound surface where the bud is inserted.

Other Horticultural Applications

During the past decade plant physiologists and horticulturists have worked intensively to discover other practical applications of the growth substances in the solution of horticultural problems. As a result of these activities many commercially important uses for the growth substances have come into general usage. Most of these uses were evolved by applying results obtained by the fundamental physiologist to the horticultural problem in question. However, some few uses have come into being simply by the horticulturists trying hormones on every problem that came along.

In so extensive a field of endeavour, it is not possible in this brief report to review in detail all of the horticultural applications. The most important horticultural uses are simply listed with an accompanying literature reference. The researcher in tropical agriculture may refer to this reference for recent information on this particular use for growth substances.

Application	*Reference*
Prevent sprouting in nursery stock in storage	Marth (1942)
Delay opening of buds on tung trees to avoid frost injury	Sell et al. (1942)
Inhibit sprouting of potato tubers	Denny (1942)
Healing of wounds	Shear (1936) and Jakes (1938)
Aid to grafting and budding	Kordes (1938) and Muller-Stall (1939)
Inhibit sprouting of rhizomes	Rappaport (1939)
Effect on gladiolus corms	Zimmerman and Hitchcock (1938)
Effect on lily bulbs	Lumsden and Stuart (1941)
Effect on orchid pseudo-bulbs	Cosper (1941)
Prevent pre-harvest fruit drop of apples	Batjer (1934)
Prevent leaf drop of holly in transit	Milbrath and Hartman (1942)
Prevent abscission of bean flowers	Allen and Fisher (1943)
Production of seedless fruits	Gustafson (1942)
Induce flowering of pine- apples	Cooper (1942)
Overcome self-sterility in plants	Eyster (1941)
Overcome cross-sterility in lily	Stuart and Emsweller (1944)
Aid in transplanting	Mitchell and Rice (1942)
Use in fertilizer mixtures	Copisarou (1942) and Swartz (1941)
Seed treatments	Swartley and Chadwick (1942) and Barton (1940)

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NATIVE FOODSTUFFS IN TANGANYIKA

The Preparation and Use of Local Foodstuffs in the Shinyanga District of Sukumaland, Tanganyika Territory

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Introduction

In the following notes th various foods commonly used by many Sukuma households in the Shinyanga district will be described. Many of these foods are cultivated by the African in his fields while others are gathered wild in the bush. Several are not only eaten fresh but are also prepared and stored for consumption at a later date when vegetable foods have become scarce. Items of interest regarding each plant have, where possible, been included together with the appropriate botanical reference. It is noteworthy that many of the pot-herbs described are known not only in Tanganyika Territory but also in other parts of Africa such as Nigeria.

Staple Foods

The basic foods which make up all African diets are in the main either sorghum, maize or millet and, to a lesser degree, cassava and the sweet potato. There are two common methods used for preparing grain foods: in each the grain is first pounded in a native mortar.

i (*a*) With sorghum the crushed seed is first washed in water and put out to drain in a flat shaped basket. It is then dried in the sun for half an hour on a piece of hide and ground between two stones, after which it is again dried until ready for either cooking or storing.

ii (*a*) With maize the crushed grain is left in a pot of water for twenty four hours, then removed, drained and immediately ground between stones without any previous drying. The ground grain is sun dried until such time as it has no smell, and can then be stored.

The same method is used for millet as for sorghum. Methods i (*a*) and ii (*a*) differ in that maize grain is harder than sorghum.

i (*b*) An alternate method for sorghum or millet is also used in which the grain is ground between stones without any previous pounding or washing in water.

ii (*b*) Similarly an alternative method for maize is, after winnowing, to clean it in water, and then drain, sun dry for three hours and finally grind. No further subsequent drying is needed.

All these grains are winnowed after pounding and the husks are thrown away, except in the case of maize when the husks are sometimes kept and can be used in the preparation of native beer.

COOKING METHODS

'Porridge'

The prepared flour is placed into a pot of boiling water, given one immediate stirring, left to boil three minutes and stirred again. If the mixture should become too thick, more boiling water is added until the desired consistency is reached (time of cooking: approximately $1\frac{1}{2}$ hours). Maize porridge is, generally speaking, preferred to that of the other grains.

'Gruel'

A pot of cold water is put on the fire and flour added. This is stirred constantly until boiling commences when it is then left for a final three minutes. Cooking takes about fifteen minutes only.

Alternatively the flesh of a Baobab tree pod is added to the flour in equal quantities but only the red seeded types of sorghum are used in this method.

Cassava and sweet potatoes can also be prepared as porridge or gruel.

Cassava Porridge

Method (*a*)—The skin is removed from the tubers and the latter are left to dry in the sun for one day. They are then pounded and sieved, the coarser parts being regrounded and sieved again. The resultant flour is cooked in the same way as for sorghum except that while it is still boiling it is taken off the fire, otherwise the porridge does not harden but remains soft. After removal from the fire continual stirring is necessary until the desired consistency is obtained.

Method (*b*)—An alternative method consists of skinning the tubers, soaking them in water for six days and on removal, sun drying for at least two days. When dry they are pounded, sieved and cooked as for maize. The resultant flour in this method is very fine and makes a very good white porridge.

Method (*c*)—In this method the tubers are skinned, sliced and sun dried for one day and then pounded, sieved and prepared as in Method (*a*).

The method for making cassava gruel is the same as that used for maize.

Sweet Potato Gruel

Stored potatoes are generally used. The slices of skinned potatoes are pounded and ground between stones in the usual way; the flour is

added to boiling water and stirred for three minutes. It is then left to boil for a further fifteen minutes, after which it is removed from the fire, cooled and strained through a native beer strainer. This gruel is often taken into the fields by those who are working there all day.

The method of making sweet potato porridge is similar to that for cassava and, in some instances, the flour may be mixed with the flour of bambara groundnuts.

Wild and Cultivated Plants

Many small crops usually interplanted with the grain crop are grown as vegetables and from these the leaf, fruit or seed may be used in the African's diet. In addition, there is a wide range of wild plants available that may also be used but of these fewer are prepared and stored as reserved foods. Naturally a family will not use all those listed, their choice being governed according to the popularity and availability of each.

In the Appendix will be found the botanical name and family of each plant together with the local name (Ki-Sukuma) and, when possible, the common name, and their availability and palatability.

Cooking and Storage Methods

It is proposed to discuss the methods of cooking the leaf, seed and fruit of wild and cultivated plants under the following main heads.

A. Cooking for immediate consumption

B. Preparation for storage

C. Cooking of stored material

It will be seen that in the case of each of the above (*i.e.* A, B, & C) standard methods of cooking and storage are used for most plants. In certain cases however, there are slight differences in procedure which it is not intended to discuss here.

A. Cooking for Immediate Consumption

Leaf

Method 1

The picked leaf is placed in a pot of boiling water, a little 'potash' salt and a pinch of 'earth' or ordinary salt is added (see under Accessories). Boiling is continued for 30 minutes when groundnut flour is added, the mixture stirred, removed from the fire and eaten together with porridge. This method is used for *Vigna sinensis* Eng. and for the following plants (cooking time for most of them is only 15 minutes) :—

Citrullus vulgaris Schrad.—a water melon type of plant and though often wild is in some parts of Africa cultivated on a considerable scale. Its fruits are often bitter.

Cucumis Melo Linn.—a common ground trailer, practically a weed and believed to be some form of the cultivated sweet melon. It is, however, propagated by the African.

Gisekia pharnaceoides Linn.—sometimes known as Herdsmans Henna. It is used as a pot herb in India in times of scarcity. It may be mixed with leaf of *Sesamum radiatum* Schum. or with *Amaranthus Blitum* Linn.

Boerhaavia plumbaginea Cav.— a scrambling sub-erect herbaceous undershrub with white, lilac or red flowers. Used with leaf of *Sesamum radiatum* Schum.

Ceratotheca sesamoides Endl.—two types, spreading and upright. It has in some parts of Africa been brought into cultivation and is used like sesame but oil is not extracted from the seed. In some places the seed is used as a food, in others the leaf. The leaf is sometimes sold as a soup vegetable on account of its mucilaginous quality.

Sesamum angustifolium Eng. and *Sesamum radiatum* Schum.—their leaves are rarely used alone. The latter has a characteristic strong odour. The seeds have a fairly high oil content and are in some countries a common adulterant of beniseed.

Commelina Forskalaei Vahl. and *Cyanotis nodiflora* Kunth.—weeds of cultivated soils or waste places and often constitute a pest in fields. Rhizomes of both weeds go deep into the ground.

Commelina benghalensis Linn. and *Aneilema Dregeanum* Kunth.—said to be cultivated in China and in India, is used as a vegetable in times of scarcity. Troublesome in cultivated fields, growing from fragments left in the soil when hoed. Leaves of these are mixed with *Sesamum radiatum* Schum.

Corchorus olitorius Linn.— a mucilaginous pot herb with young leaves, often a useful substitute for European spinach. It is mixed with leaf of *Vigna sinensis* Eng.

Portulaca oleracea Linn.— regarded in some parts of Africa as an antiscorbutic plant. Several cultivated varieties have been produced in Europe as a vegetable. Roasted seeds are used in Australia. It is mixed with leaf of *Sesamum radiatum* Schum.

Tribulus terrestris Linn.—its fruit is a kind of caltrop rendering it a pest on footpaths, fields and waste places to both man and cattle. It can be mixed with leaf of *Amaranthus Blitum* Linn. or *Sesamum radiatum* Schum.

The leaf of the following plants are all used in conjunction with that of *Sesamum radiatum* Schum. :—

Ipomoea Batatas Poir, Cucumis ficifolius A. Rich., *Cucumis dipsaceus* Ehrenb., *Hygrophila spinosa* T. And., *Hibiscus intermedius* A. Rich., *Corchorus trilocularis* Linn., *Oxygonum atriplicifolium* var *sinuatum* Bak., *Vigna triloba* Walp, *Trichodesma zeylanicum* R. Br. and *Anthericum subpetiolatum* Baker.

Amaranthus Blitum Linn. and *Achyranthes aspera* Linn. are mixed with *Gynandropsis pentaphylla* D.C., *Cleome hirta* (Kl.) Oliv. is mixed with *Amaranthus Blitum* Linn., and *Sonchus Bipontini* Asch. with *Vigna sinensis* Eng. *Cucumis* sp. Koristchner 3084 is used on its own.

Method 2

Picked leaves are pounded in a mortar and placed in a cooking pot of cold water. Here they are boiled dry three times, each time the water added being just sufficient to cover the leaf, this is due to the toughness of the leaf, and takes about 3½ hours. Groundnut flour and salt is then added and the mixture on stirring is ready. This method is adopted for *Manihot utilissima* Pohl. and *Manihot* sp.

Method 3

Used for *Agaricus campestris* L. Fr.—'The Mushroom'—the plants are uprooted whole, cleaned in water, placed entire in a pot of cold water and boiled for 15 minutes. Groundnut flour and salt are then added.

Seed

Method 1

Used for seeds of *Vigna sinensis* Eng., *Phaseolus Mungo* Linn. and *Voandzeia subterranea* Thouars.

The seeds are crushed—not too finely—winnowed, placed in a pot and just covered with water. The pot is boiled nearly dry when groundnut flour and salt are added. On stirring the mixture is ready.

Method 2

Used for *Sesamum orientale* Linn.—Plants of which the seeds must be fully ripe are cut down and tied in bundles. These are stacked near the homestead, left for 15 days to dry out completely and shaken into a basket. They may be eaten roasted with salt and a little water or they may be ground between stones and the resultant flour boiled for 15 minutes together with some groundnut flour.

Method 3

Used for *Arachis hypogaea* Linn.—These may be roasted with salt and are often eaten with potatoes boiled in their skins. A normal family will use about half a sackfull of shelled nuts in a year chiefly in the form of flour mixed with the vegetables.

Fruit

Method 1

Used for *Citrullus vulgaris* Schrad.—The fruits are sliced, the seeds removed and the pieces placed in an empty pot. No water is needed as the fruits' own juice is sufficient. After 20 minutes boiling, salt and groundnut flour are added and on stirring the mixture may be eaten either hot or cold.

Method 2

Used for the fruits of the Baobab tree (*Adansonia digitata* Linn.) and the Indian Tamarind (*Tamarindus indica* Linn).

The seed pods are broken open, the flesh extracted and placed to soak in a pot of cold water for 30 minutes. The seeds may then be removed. Groundnut flour is added to the pulp and the stirred mixture, needing no cooking, is eaten with porridge.

B. Preparation for Storage

Leaf

Method 1

Used for *Vigna sinensis* Engl., *Gynandropsis pentaphylla* D.C., *Ceratotheca sesamoides* Endl., and *Manihot* sp.

Leaf picked in the field is sun dried near the house for about 4 hours. It is then placed in a pot and cold water not quite covering the leaf is added. This is usually done in the evening. Cooking is continued for some three hours and midway during this period, the water in the pot is changed. On removal from the fire, there being only a little water left, it is covered with a smaller pot and left. Next morning the leaf is removed, pounded and sun dried until early afternoon. It may then be stored in a pot where it will keep upwards of one year.

Method 2

Used for *Crotalaria microcarpa* Hochst and *Ipomoea eriocarpa* R. Br.

The whole plant is uprooted, sun dried for a day and the leaves rubbed off. Leaf may be stored (up to 1 year) without any cooking being necessary.

Method 3

Used for *Agaricus campestris* L. Fr.

The plant is placed in cold water, boiled for 15 minutes, removed, sun dried for 3 days and may then be stored.

Fruit

Method 1

Used for *Citrullus vulgaris* Schrad.

The fully grown fruits are skinned and sun dried for two days (in July). On the third day they are sliced, dried for a further six days and may then be stored in a large pot.

C. Cooking of Stored Material

Leaf

Method 1

Used for *Vigna sinensis* Eng., *Gynandropsis pentapyhlla* D.C., *Ceratotheca sesamoides* Endl. and *Manihot* sp.

When required the leaf is placed in a warm cooking pot together with groundnut flour, salt and a little hot water. The mixture is stirred, left for a while and eaten later with porridge. Alternatively a cupful of warm milk may be substituted for the water.

Method 2

Used for *Crotalaria microcarpa* Hochst. and *Ipomoea eriocarpa* R. Br.

Leaf is mixed with *Sesamum radiatum* Schum., ground between stones, placed in a pot of warm water together with some groundnut flour and boiled for 15 minutes after which salt is added.

Method 3

Used for *Agaricus campestris* L. Fr.

When required the plants are placed in cold water and boiled for 1 hour when groundnut flour and salt are added and the mixture stirred.

FRUIT

Method 1

Used for *Citrullus vulgaris* Schrad.

When required the pieces are put in a large pot with cold water and boiled for 1½ hours, three additions of water are usually made. Salt and groundnut flour are added and the mixture on stirring is ready.

Additional Foods

In addition to the staple foods already discussed the African further supplements his diet with fruits, milk, beer etc. as follows :—

1. FRUIT

(*a*) *Papaw*

Used in two ways :—

(i) Eaten fresh as a ripe fruit.

(ii) Used as a vegetable when fruit is unripe. The skin is removed, the fruit sliced into pieces and the seeds are removed. The pieces are then put in a pot of cold water and boiled for one hour; when soft, groundnut flour is added and the mixture on stirring is ready to be eaten. The fruit is available approximately between the months of June and September.

(*b*) *Banana*

(i) Eaten as a ripe fruit.

(ii) Eaten also when semi-ripe. The skins are removed and the whole fruit is placed in a pot of cold water (Note : the Swahili prefer to slice the fruit). It is boiled for two hours after which salt and groundnut flour are added. This food is generally eaten on its own and is available at most times of the year.

(*c*) *Mango*

(i) Eaten as a ripe fruit.

(ii) Fruit in its unripe stage can be used as a flavouring for meat dishes. When the water cooking the meat is beginning to boil skinned slices of the fruit are added and this gives the meat a lemon like flavour.

(*d*) *Tomatoes*

The seeds of this plant are usually sown on a patch near the homestead—succeeding crops being usually self sown.

(i) The fruit when used fresh is mixed with the leaf of cow pea that has been prepared as a reserve. The squashed tomatoes less the seeds together with the cow pea leaf are placed in a pot of hot water and boiled for ten minutes, when a little groundnut flour and salt are added. This mixture is generally eaten together with the staple porridge.

(ii) The fruit is also used together with the fresh leaf of *Citrullus vulgaris* Schrad. A cooking pot of cold water and containing the fruit is boiled and when boiling commences the leaf is added. Boiling is continued for a further 15 minutes after which groundnut flour and salt are added. The mixture on stirring is ready.

(iii) Tomatoes are also stored. The fruit is squashed to remove the seeds and put out in the sun to dry for about six days, when it can then be stored in a pot. When required for use the same method as (i) is adopted.

(iv) Tomatoes can be added to meat or fish dishes.

2. MILK

Whole milk or butter milk may be drunk with porridge, with cow pea leaf mixture which has been stored, with boiled potatoes or with potatoes that have been previously stored. It is also taken sometimes with roasted groundnuts.

3. MEAT

This is usually boiled in water for about four hours. Butter, pepper, salt or tomatoes may be added. Meat is also roasted and eaten with porridge.

4. DRIED FISH

The fish is first cleaned in water and then placed in a pot of cold water. Whilst boiling a little butter ghee, salt, pepper or tomatoes may be added. If no butter is available groundnut flour can be substituted.

5. NATIVE BEER

This is made from sorghum and usually the red seeded types are used. There are four distinct processes each of which has an appropriate native name. The process as will be seen is neither simple nor short.

(*a*) One petrol tin (4 gallon) of sorghum together with one small feeding bowl of wood ash is put in a large earthenware cooking pot with water. Here it is left to soak. The addition of ash apparently is said to cause the subsequent sprouting to be quicker and more even and tends to make the resultant beer slightly sweeter in taste. The following morning, the water is drained off and the grain is well washed in fresh clean water in order to remove the solid ash. The water is drained off and the seed is put inside the hut on a skin and left for two days to sprout. On completion of this the sprouted grain is placed in the sun to dry out and stop further sprouting—this takes up to two days according to the weather. When dry the grain is semi-finely ground between stones and three small feeding bowls of maize husks are added to it. Next, two feeding bowls of fresh sorghum seed are ground and added to the mixture. Water in the meantime is brought to the boil in another large cooking pot and added to the dry mixture that has been put back into the first. Here it is left for two days. During the second day it is tested from time to

time, the end of this part of the process being determined by a lemon-like bitterness and by the gummy-like nature of the liquid.

(*b*) The liquid having reached this stage is poured off into several smaller cooking pots each of which is boiled for seven hours, being constantly stirred.

(*c*) After the boiling period the liquid is repoured into the large pot and is left to cool inside the hut for two days. During this time another petrol tin of sorghum is 'sprouted' and part ground. The original mixture, now cool, is in the evening again redivided into the smaller pots and the newly sprouted grain is equally added to them. The liquid is stirred and allowed to bubble. This addition of sprouted grain may possibly cause the sugar content of the mixture to form alcohol together with CO_2 (bubbling), as would occur if yeast was added instead. Bubbling of the mixture continues from evening until the next morning.

(*d*) A petrol tin of ground sorghum is now placed in equal parts into four other receptacles containing boiling water. These are allowed to stand for five minutes after which the liquid is poured off into one large pot, stirred and cooled. When cool, equal proportions are mixed with the original liquid, stirred and filtered through a platted filter. When it has all been thus treated the beer is ready and there should be some twenty eight gallons in all. The brew in addition to being a good drink is most sustaining and said to have quite a good food value. Its preparation takes some seven days. On "normal" occasions a man will consume about one gallon, a woman half a gallon and children are allowed about a quarter of a gallon between ten of them.

Condiments and Accessories

1. Salt

Salt in addition to being bought from the local Indian may be prepared from certain soils that are to be found above the water mark of rivers near this area. The preparation is done 'in situ'. A stand three foot high is built and on top of this an old flat basket containing the collected soil is placed. Water is poured over the soil and the filtrate obtained is collected in a pot below the stand. When some eight gallons of filtrate have been collected it is boiled dry in a large pot and from this a small feeding bowl of salt is obtained. This is sun dried for one day. A normal family of four will use about one petrol tin of salt in a year.

2. "Potash" Salts

These are prepared from the following grasses:—

(A) *Justica matammensis* Oliv. (Acanthaceae).

(B) { *Trianthema pentandra* Linn. (Aizaceae) 'Horse Purslane'
Chenopodium album Linn. (Chenopodiceae) 'Pig weed'

From these pot herbs salts are prepared and from their local name, may be termed "Potash" salts. *Trianthema pentandra* Linn. forms a close growth over waste places and salt is obtained from it in other places such as West Africa. The use of these salts in native cooking is not only that of a condiment but also as a leaf softener. Thus in some plants such as the cultivated gourd types the leaves have small spines and the removal of these is aided in the cooking by the addition of these salts, the spines being skimmed off the water with a ladle. In addition to the mechanical aid afforded, the cooked leaf is also more palatable. There is a slight difference in the methods used for obtaining salts A and B. In the former cold water is poured through the ashes of the burnt leaf and the filtrate collected. In the latter the same process is used but the liquid filtrate is boiled dry giving the solid salt. The resultant salts of B are much stronger than those contained in the liquid filtrate and only a pinch need be added to the cooking leaf. The addition of A, however, may be in liquid form. A normal family uses about two small feeding bowls of the solid salt in a year.

3. Pepper or Chillies

Method of preparation:—If it is to be used with any other green food the pod is pounded in a small bowl and can then be used. It may also be prepared for storage. In this case the pods are sun dried for a week after which they can be placed and kept in a small cloth bag. When required the pepper is ground as before and sprinkled onto the food. Pepper when ground fine may be used together with fresh cooked leaf or it may be added to groundnut flour. The whole pods may also be mixed with leaves that are being prepared as a reserve food.

4. Butter

This is used with meat or fish. About one large desert spoonful is added to the boiling meat when the latter has become well cooked and about half an hour before its removal from the fire.

5. Ghee

This may also be used with meat or fish. It is added to meat three minutes only before the pot is removed from the fire. It is occasionally used with vegetables that have been kept stored.

6. Honey

Used with porridge, the latter being dipped into a bowl of it. Honey may be added to gruel when the pot is still on the fire, or with boiled sweet potatoes.

Storage Notes

1. Sweet Potatoes

There are two methods of storing sweet potatoes. Method "A":—the dug potatoes are sun dried for three days and on the fourth sliced. The pieces are then dried for a further four days. They can then be put in a large platted and covered basket and can remain there for six months. Most

varieties can be treated thus although the smaller potatoes generally are used. When required for use the slices are placed in a pot of boiling water and cooked for half an hour. When ready they may be eaten with roasted groundnuts and milk. These slices may also be used in the preparation of gruel. Method "B" :—here the dug potatoes are sun dried for three days, placed in a pot of cold water and boiled dry in about two hours. The potatoes are removed from the pot and placed in a flat basket where they are peeled and sliced. A rack of sorghum stems is built and the slices dried on this for seven days, remaining out at night. After this they are stored and can remain in storage upwards of five years. This method is generally used for the larger potatoes and for most varieties. It is a more satisfactory method than the first as not only do they keep longer but are less liable to weevil attack. Preparation by either method is done in July. When potatoes stored by Method B are required the slices are placed in a pot of boiling water and cooked for two and a half hours.

2. Grains

These are usually stored as are potatoes in large plaited baskets made from withies and with a smearing of dung inside and out. They are fitted with a lid and stand several feet high feet (5) often raised above ground level. Maize may be stored either on the cob or as grain. Groundnuts too are stored this way.

3. Vegetables (Leaf)

(*a*) Pot herbs that have been prepared for reserve purposes can be stored in covered earthenware cooking pots.

(*b*) Some pot herbs such as *Cucumis Melo* Linn. are kept thus :—Six foot lengths of bush rope are laid on the ground side by side with narrow spaces between. Dried sorghum stalks are laid on top and the leaf to be stored is placed on top of this. The ends of the rope are pulled up from each end and tied together. The whole is then suspended from a tree or under the eaves of the house.

(*c*) Another method such as used for *Vigna sinensis* Eng. is where seven lengths of bush rope are laid out and grass placed on top. The leaf is put on next and then more grass. The rope ends are pulled up and tied together. A forked stick is pushed into the bundle, from the fork end and then stuck upright and firmly in the ground.

Acknowledgments

The writer is greatly indebted to Mr. P. J. Greenway, Systematic Botanist of the East African Agriculture Research Station, Amani for his help in indentifying the majority of the pot herbs, and to Mrs. H. E. Hornby, late of Old Shinyanga T.T. for identifying others.

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Appendix

	Botanical Name	*Family*	*Kisukuma Name*	*Common Name*	*Availability*	*Palatability*
1.	*Achyranthes aspera* Linn.	Amaranthaceae	Luhululilanghanga..	—	Dec.—Aug...	Low
2.	*Adansonia digitata* Linn	Bombacaceae	...Mandu	...Baobab Tree..	..June—Oct.	High
3.	*Agaricus campestris* L.Fr.	Agaricaceae	..Boba	..Field Mushroom	..Feb.—March	High
4.	*Amaranthus Blitum* Linn.	Amaranthaceae	Moga	.. —	..Jan.—July	High
5.	*Aneilema* Sp.	..Commelinaceae	..Siza	.. —	..Nearly always	Low
6.	*Anthericum subpetiolatum* Baker.	Liliaceae	..Kugulukumo	.. —	..Nov.—Dec.	Low
*7.	*Arachis hypogea* Linn.	Leguminosae	..Nhalanga	..Groundnut	..April—June	High
8.	*Boerhavia plumbaginea* Cav.	Nyctaginaceae	..Kalitongo	.. —	..Nov.—July	Low
9.	*Ceratotheca sesamoides* Endl.	Pedaliaceae	..Malendi ga wima Malendi ga twege	—	..Dec.—July	High
10.	*Chenopodium album Linn.*	Chenopodiceae	..Nyambo	..Pig Weed	.. — ..	—
*11.	*Citrullus vulgaris* Schrad.	Cucurbitaceae	..Masindi	..Water Melon	..Jan.—July	High
12.	*Cleome hirta* Kl. Oliv.	Capparidaceae	..Kagunguni	..Spider Flower or Bastard Mustard	Dec.—July	Average

* Cultivated types.

Appendix—*Contd.*

Botanical Name	*Family*	*Kisukuma Name*	*Common Name*	*Availability*	*Palatability*
13. *Commelina benghalensis* Linn.	Commelinaceae	Kashoholelo	—	Dec.—June	Low
14. *Commelina Forskalaei* Vahl.	do.	Tiza	—	Nov.—July	Average
15. *Corchorus olitorius* Linn.	Tiliaceae	Wibila	—	Nov.—July	High
16. *Corchorus trilocularis* Linn.	do.	Kala	—	Dec.—July	High
17. *Crotalaria microcarpa* Hochst. ex Benth.	Leguminosae	Mikuli	—	Feb.—July	High
18. *Cucumis. dipsaceus* Ehrenb.	Cucurbitaceae	Limbi lugulu	—	Nearly always	Low
19. *Cucumis ficifolius* A. Rich.	do.	Kasasala	—	Nearly always	High
*20. *Cucumis* Sp. Koristchner 3084	do.	Gogo	—	Jan.—June	High
*21. *Cucumis Melo* Linn.	do.	Limbi	—	Jan.—June	High
22. *Cyanotis nodiflora* Kunth.	Commelinaceae	Tiza	—	Nov.—July	Average
23. *Gisekia pharnaceoides* Linn.	Molluginaceae	Ngalagalilisonga	—	Dec.—May	Low
24. *Gynandropsis pentaphylla* D.C.	Capparidaceae	Ngagani	Cats Whiskers	Jan.—July	High
25. *Hibiscus intermedius* A. Rich.	Malvaceae	Lulimulwangoni	—	Nearly always	Average
26. *Hygrophila spinosa* T. And.	Acanthaceae	Samangombe	—	Dec.—Aug.	Low
*27. *Ipomoea Batatas* Poir.	Convolulaceae	Matembele	Sweet-Potatoe	June.—Sept.	High
28. *Ipomoea eriocarpa* R. Br.	do.	Matungoso	—	Nov.—Dec.	Low
29. *Justica matammensis* Oliv.	Acanthaceae	Masesa	—	—	—
*30. *Lagenaria vulgaris* Ser.	Cucurbitaceae	Ntwaligana	Calabash Gourd	Feb.—Aug.	High
*31. *Manihot utilissima* Pohl.	Euphorbiaceae	Kisafu	Cassava	1st, 2nd, 3rd year old plants	High
*32. *Manihot* Sp.	do.	Kayeba	—	Once a month for six years	High
33. *Oxygonum atriplicifolium* var. *sinuatum* Bak.	Polygonaceae	Ikilayangholo	—	Dec.—Aug.	Low
*34. *Phaseolus Mungo* Linn.	Leguminosae	Ndulu	Black Gram	March	High
35. *Portulaca oleracea* Linn.	Portulacaceae	Mborondito	—	Dec.—July	Low
36. *Sesamum angustifolium* Eng.	Pedaliaceae	Malendi	—	Nov.—June	Average
*37. *Sesamum orientale* Linn.	do.	Buhonya	Simsim or Sesame	May—June	High
38. *Sesamum radiatum* Schum.	do.	Malendi	—	Nov.—July	Average
39. *Sonchus Bipontini* Asch.	Compositaceae	Lusunga	—	Dec.—Aug.	Low
40. *Tamarindus indica* Linn.	Leguminosae	Bushishi	Indian Tamarind	Aug.—Oct.	High
41. *Trianthema pentandra* Linn.	Aizaceae	Nyambo	Horse Purslane	—	—
42. *Tribulus terrestris* Linn.	Zygophyllaceae	Shokolo	—	Dec.—July	High
43. *Trichodesma zeylanicum* R. Br.	Boraginaceae	Magundulu	—	Nearly always	Low
*44. *Vigna sinensis* Eng.	Leguminosae	Shili	Cow Pea	Jan.—July	High
45. *Vigna triloba* Walp.	do.	Kashishili	—	Nov.—July	Average
46 *Voandzeia subterranea* Thou.	do.	Mhande	Bambara Groundnut	April	High

* Cultivated types.

RUSTY WATER AND MALARIA

We have received a report by Mr. K. B. Williamson, malaria research officer, Penang (c/o Ross Institute of Tropical Hygiene, London School of Hygiene and Tropical Medicine, W.C.1) on an "Investigation of Ferruginous Waters in relation to the Breeding of Malaria-carrying Mosquitoes". It is a common observation among malariologists in the tropics that waters containing rusty deposists or bearing iridescent surface films of precipitated iron are generally free from mosquito larvae, and the possibility of utilizing this fact for the control of mosquito breeding has often been mooted. But exact information about the composition of waters of this kind and about the source of the iron has been wanting. Mr. Williamson's report is based on the examination of various types of rusty waters on Hampstead Heath and elsewhere in the neighbourhood of London and around Malvern, as well as upon his experiences in Malaya. It deals mainly with questions of chemistry.

Iron occurs in water: (1) in particulate form as colloidal ferric hydroxide ("iron rust"), the particles being so small that the water is quite clear; it is this colloidal iron which is unstable and readily gives rise to solid aggregates in the form of surface films or precipitates; (2) in true solution as ionized salts of ferrous or ferric iron; (3) as non-ionized organic complexes.

The humic matter derived from the slow rotting of excess vegetation present in soil combines with both ferrous and ferric iron and exerts a stabilizing influence on the colloidal ferric oxide. Humic matter is itself antagonistic to the breeding of most species of malaria-carrying mosquitoes. Excess of rotting vegetation in contact with the soil will thus exert a dual benefit.

A provisional attempt has been made to classify ferruginous waters. A ferruginous water is defined as one that contains a minimum of two parts per million of iron in solution or colloidal suspension. Many so-called "rusty" waters show merely a deposit of rust-coloured sediment which has been thrown down at an earlier date; a deposit of this kind affords no proof that the water continues supercharged with iron. On the other hand, superficial films of "rust" supply a more immediate indication of the presence of an unstable excess of iron in water. Such iron may be derived (i) from underground mineral sources such as pyrites, (ii) from vegetation rotted under anaerobic conditions in marshy soil, the iron containing humus forming organic complexes with the iron present in the superficial soil, or (iii) in small amount, from the rotting of vegetation alone in the water.

On the biological side the work is incomplete. Observations on the natural fauna and flora of ferruginous waters have been rather limited; but such waters are characterized by an almost complete absence of water insects, aquatic helminths, Crustacea and Algae. It has been found by experiment that mosquito larvae (*Anopheles maculipennis* var. *atroparvus*), newly hatched from the egg, are unaffected by the iron-containing waters provided they are fed; but when placed in samples of such waters without added food they soon die of starvation. It is, therefore, concluded that mosquito larvae fail to develop in rusty water from lack of food, which is ascribed in the main to the inimical effects of colloidal iron upon the growth of Algae, Protozoa and other micro-organisms. There is no evidence that iron-containing surface films will suffocate the larvae.—(*Nature*, Vol. 154, No. 5918, 1944.)

BUSH ENCROACHMENT

In the northern Transvaal, bush encroachment is a problem even more serious than soil erosion. It is taking place over the entire sweet-veld, an area of about 11,500 sq. miles, and most of the mixed veld, about 23,600 sq. miles, and is resulting in a marked decrease in carrying capacity. During the course of investigations at the Towoomba Pasture Research Station, it has become apparent that the invasion of veld by thorny and non-thorny bush is a 20th century phenomenon and that the rate of invasion is increasing year by year. A concrete and by no means isolated instance is an 8,000-morgen property situated in the Potigieters-rust district. Except for a small corner where a few scattered thorn bushes occurred, this property was devoid of bush a mere 25 years ago. Today the entire farm is covered with thorn bush; over thousands of acres of chocolate turf, lekkerruikpeul has become so dense and strong as to inhibit the growth of grass completely.

To prevent encroachment and establish a stable relationship between bush and grass-veld it is suggested that all existing young and immature bush be killed to the ground every 4 or 5 years. Controlled periodic burning is another measure suggested but artificial destruction is considered best.

Large bush can be eradicated by application of paraffin to the bark over a distance of 1 in. above and 3 in. below the junction of root and stem. This method has given 80 to 90 per cent. kill at a cost of 2s. 9d. per 100 bushes destroyed. In dealing with sekelbos, care should be taken not to sever any root because of the plant's capacity to produce stem growth from any cut root. Medium and small-sized bushes can be chopped off just below the junction of root and stem at a cost of 2s. 0d. per 100 medium sized, and 1s. 8d. per 100 small sized bushes destroyed. Shallow rooted species can be uprooted.—(*Herbage Abstracts*, Vol. 14, No. 4.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Process of Formation of Active Humus of the Sod Type

A necessary condition for the formation of active humus of the sod type, capable of combining with mineral colloids to form stable aggregates, is that the fungal process with which the aerobic decomposition of plant processes usually starts should be quickly and energetically superseded by predominantly bacterial processes. This is promoted by a neutral reaction of the medium. Thus, liming podzol soils leads to the accumulation of glutinous organic substances active in aggregate formation.

The most significant factor in the formation of active humus is the bacterial microflora of the rhizosphere of perennial grasses. Bacteria of the type of *Pseudomonas*, which are dominant in the rhizospheres of many meadow grasses, are particularly strong structure-formers to which may be attributed the stable structure formed during the growth of grasses. These bacteria thrive best under neutral conditions. Thus a neutral reaction is necessary both to promote a rich rhizosphere flora during growth of perennial grasses, and to ensure the predominance of bacterial processes in the subsequent decomposition of the grasses.—(*Soils and Fertilizers*, VII, No. 3, 1944. *See* F. Yu, Gel'tser, *Pedology*, No. 9-10, 1943)

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Notes on Citrus Fertilization

According to an article in the *Calif. Citrogr.*, 1944, 29: 118, the most common deficiency in Californian citrus orchards is nitrogen while less common deficiencies are zinc, copper and manganese A generally satisfactory annual nitrogen application is 2 to 3 lb. per tree or 10 to 15 lb. of a 20 per cent. N fertilizer. At least half the nitrogen requirement can be supplied by farm yard manure or some similar organic material. Zinc is best supplied as 5 lb. zinc sulphate, 2½ lb. hydrated lime or soda ash, water 100 gal., or zinc oxide 2 or 3 lb., water 100 gal., a formula which may cause some burning. Treatment should be supplied often enough to prevent mottle leaf and is most effective if applied at the beginning of a growth flush. Copper may be supplied by 5-5-100 Bordeaux mixture, manganese by 3 lb. manganese sulphate, 1½ lb. soda ash, 100 gal. water. Three to 5 gal. sprayed on a mature tree is enough. Fumigation should not follow for at least 8 months. Soil applications have not been effective in California. The importance of using a leguminous rather than a non-leguminous cover crop is stressed. The cost often outweighs the benefit of cover crops. The formation of nitrite (NO_2) and its toxic effects on the trees are discussed. Its importance and prevalence are not yet fully understood. Farm yard manure should be applied in late summer or early autumn. Nitrogen should be broadcast and, where leaching is a factor, applied in several small doses.

Soil Fertility Experiments in South Africa

The Agricultural Research Institute, Pretoria, is carrying out large-scale experiments on soil fertility. Investigation into the effect of climate on the availability of plant nutrients has shown that the soils are not deficient in phosphorus, as is commonly believed, but that a heavy rainfall is required to make the phosphorus available to the plant. Availability of nitrogen, on the other hand, is not reduced by a dry climate.

The Institute has no fewer than 366 irrigated plots to test the effect of various fertilizers on irrigated crops under two rotational systems. Erosion control is being studied on erosion plots having a 3.75 per cent. slope and on run-off plots with a 7 per cent. slope. Some alarming results on the rate of erosion have been obtained. "Under arable crops the amount of run-off has been found to amount to approximately 20 per cent. per annum of the rainfall, with a rate of erosion of approximately 10 tons to the acre per annum. Bare soil, uncultivated over the period of the experiments, has given an annual run-off of about 45 per cent., with nearly 20 tons of soil per acre eroded annually. In striking contrast, undisturbed veld has given a run-off of less than one per cent. while the amount of erosion in this case is so small as to be hardly measurable.

Percolation experiments have shown that little water is lost when a crop is growing, but that in uncultivated ground the loss may be 12.5 per cent. of the annual rainfall. The nitrogen losses on the cultivated and uncultivated plots are 75 lb. and 400 lb. per acre per annum.—(*Herbage Abstracts*, Vol. 14, No. 4.)

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Production of "Water Shoots" in Cane

According to a paper in the *Proceedings* of the *11th Annual Convention, Sugar Technologists' Association*, India, Part I, 1942, pp. 19-23, water shoots are late tillers from the cane stool, which usually grow very rapidly. Their juices are usually of low purity and low Brix, due to high water content. In some cases the weight of these water shoots may be nearly a third of the total weight of the crop, resultant in a considerable increase in the tons of cane required to make a ton of sugar. The predominant factor in the production of water shoots is wide spacing, which may be either intentional on the part of the planter or brought about by deficient germination of the plant cane, or by borer damage or by lodging. The stools that are thus given more sunshine and space throw out new tillers instead of promoting the growth of the older stalks. The remedy is to secure uniform and vigorous germination and early tillering, and avoid heavy applications of nitrogenous fertilizers that cause lodging. Increased application of phosphate may be a help.—(*Sugar*, Vol. 38, No. 12, 1943.)